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# Mapping research at the intersection of organic farming and bioenergy — A scientometric review

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ABSTRACT

Modern bioenergy systems have received growing attention for their potential as a substitute for fossil fuels and are strongly promoted in many regions. At the same time large scale industrialized farming in general and intensive energy cropping in particular are increasingly drawing criticism from various stakeholders. Organic farming systems seem to successfully tackle agricultural sustainability questions at least in regard to ecological dimensions. Still, apart from chemical inputs organic systems are as much dependent on non-renewable energy sources as conventional systems. This article deals with the question whether the topics of organic farming (OF) and bioenergy (BE) are at all combined or addressed in alliance within scientific literature. By means of descriptive scientometric measures the present study analyzes OF- and BE-literature retrieved from Thompson Reuters' Web of Science database in order to generate insights on development, dynamics, structure and distribution of OF/BE-research literature. Despite possible barriers for research in this interdisciplinary sub-field and its current niche character we conclude that research efforts in OF/BE might be expedient and scientifically rewarding.



**Contents**



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## 1. Introduction

In view of limited natural resources and the ecological and socioeconomic crises of the past 30 years [1,2] two major global challenges have emerged: the sustainability of energy supply and the sustainability of agricultural land-use systems. Over the past three decades two prominent approaches to meet these challenges have evolved: (i) the substitution of fossil energy sources with renewable ones and (ii) the development of more sustainable farming systems. The advancement of renewable energies has led to a strong expansion of modern bioenergy systems. Organic agriculture – a low input farming system emulating natural closed cycles of matter – has been promoted as more sustainable farming system and raised scientific and political attention. However, both approaches may be falling too short and are drawing criticism for different reasons. Agricultural biomass production for energy generation poses new threats to the sustainability of land-use systems, whereas organic farming is also depending on and extensively using fossil fuels. So not only are bioenergy and organic farming merely partial solutions to sustainability issues but they are also interconnected. Hence, a combined perspective of the two might benefit efforts to meet current global challenges.

This study therefore examines agricultural and bioenergy research literature to analyze the status of the two topics, organic farming and biomass energy, in agricultural and renewable energy science. The descriptive scientometric measures applied here provide insights on the general development of scientific publication fields. Thereby, this study quantitatively analyzes abundance and dynamic of publications on two highly relevant topics of sustainable development. With the help of the scientometric indicators we show to what extent journal publications are taking a concurrent view on organic agricultural systems and bioenergy. Furthermore, bibliometric data allow us to analyze the structure and distribution of scientific interest in the combination of organic farming and biomass energy issues. Information on authors, institutions, and journals of the analyzed papers are compared. Thereby, the focus within the disciplines of agricultural and bioenergy sciences as well as regional "hot spots" of this particular research interest are identified.

The article is structured as follows. First, the views and challenges on energy and agriculture are briefly described and problems of resource allocation connected with bioenergy and farming are reviewed from both angles. Subsequently, a coherent view elaborates on the rationale of combining the two topics—thereby elucidating the starting point for our review and presenting previous research relevant to our study. In the methods section detailed information is presented on the literature search and a brief introduction to the scientometric measures applied is given. Results are presented for (i) development and dynamic of the research fields and (ii) structure and distribution of publications.

After the results are discussed the paper concludes with recommendations for stakeholders and a general appraisement of the study.

### 1.1. The energy angle

Traditionally, the production, conversion and utilization of biomass for energetic purposes has been an integral part of agricultural systems [3]. Biomass covered agriculture's internal energy needs and in some cases also ensured nutrient cycling [4]. Before the modern agricultural revolution in industrialized countries, energy consumption for farming was mainly based on solar energy; either directly (e.g. in post-harvest processes such as drying) or indirectly through biomass energy (e.g. through photosynthesis in fodder crops for animal draft power). The decoupling of agricultural and energy production during the 20th century made it possible for farmers to concentrate on cash crop production, which was backed and accelerated by the industrialization of food systems. This agricultural transformation has mainly been based on [5–8]:

- *fossil fuels* replacing bioenergy sources for tillage and nitrogen fixation,
- increased use of *external inputs*,
- *new technologies* often associated with fossil fuel and material inputs,
- as well as *knowledge*.

However, there is growing evidence for and increasing concern about [9–11]

- environmental limits on continued high dependence of agriculture on fossil fuels and materials,
- rising prices of energy and material inputs, as well as
- competition between food and energy production.

Furthermore, while various positive feedbacks have supported development processes in the past (e.g. increased productivity, capital accumulation, improved health, etc.) some of these may be reaching their limits while negative repercussions of fossil fuel use become increasingly important. These encompass limits to fossil and natural resource availability (e.g. oil, land), loss of natural resources due to over-exploitation (e.g. water) and degradation (e.g. soils), reduced productivity due to waste or pollution, as well as emission induced climate change and the associated losses of (agro-)ecosystem biodiversity, stability and productivity.

Against this backdrop interest in renewable energies has grown and led to a boost in bioenergy (BE) utilization in many regions in recent years. Regarding the main sources of biomass – agriculture, forests and waste – agricultural biomass is generally considered to have the greatest energy potentials [12]. To unlock and utilize these potentials in a sustainable manner remains a major challenge [13]. While biomass energy production seems inevitable to curb negative effects of greenhouse gas (GHG) emissions from non-renewable resources and to replace depleting fossil fuels [14], questions of sustainability regarding biomass production in conventional agricultural systems arise [15–17] and more sustainable BE-systems have been called for [18,13].

### 1.2. The agricultural angle

Agricultural land-use has been drawing continuous criticism due to associated negative external effects of intensive farming practice. Pivotal developments in modern agriculture that have led to doubts regarding the long-term viability of current production systems have been summed up e.g. by [19]. Agricultural sustainability has been investigated in various aspects such as environmental pollution, biodiversity, resource efficiency, GHG emissions, land degradation, soil erosion, rural livelihoods, animal welfare, and economic viability of farming systems. The concept of agricultural sustainability has long been discussed in science [20], yet the common focus is often limited to environmental and ecological dimensions of agricultural systems. Limited and/or depleting resources (land, water, fossil fuels, phosphorus, etc.), an evergrowing demand for agricultural products (food, fiber, fuel, raw materials for industry) as well as repercussions from environmental externalities of industrialized farming have led agricultural scientists to examine, evaluate, and compare different agricultural production systems [21–24].

An agricultural production system frequently stated to be sustainable is organic farming. Modern organic farming (OF) as defined by the International Federation of Organic Agricultural

Movements (IFOAM) is often viewed as a sustainable land-use system due to its beneficial environmental effects and the reduction of negative externalities [25]. The four constituent IFOAM Principles of (i) health, (ii) ecology, (iii) fairness and (iv) care encompass all three sustainability dimensions. The principles aim at the establishment of an environmentally and ethically sound agricultural production system. Over the past three decades, organic agriculture has attracted substantial scientific attention [26] in reaction to the challenges posed on land-use, health, food supply, and eco-system functions. Although evidence in some aspects is disputed [27], at least from an environmental perspective agricultural research has confirmed that OF-systems in many regards are in fact more sustainable [28,29,23].

However, regarding its energy needs modern OF- systems must not be underestimated. Although the energy efficiency in OF is higher than in comparable conventional systems [30,23], the question of sources of energy consumed in OF is important when discussing the system's sustainability [31]. In most cases, especially in modern mechanized production and processing systems, organic agriculture as well is strongly dependent on fossil fuels [32].

### 1.3. A coherent view?

So the question arises whether there is scientific interest in the alliance of OF and BE? Taking into account the relevancy elaborated above of the OF and BE topics in regard to current sustainability questions and the general conception of science tackling the pressing societal challenges lead to the hypothesis that there is research activity at the intersection of organic agriculture and bioenergy.

There have been conceptual attempts to sum up the key topics of BE-production within OF- systems earlier [33,34]: e.g. trade-offs in sustainability or contradictions of BE with organic principles, as well as issues arising from possible conflicts between the current industrialized biomass production systems on one hand and organic food production on the other (e.g. competition for rented land). To the knowledge of the authors, however, no study has been published that might render conclusive scientometric or bibliometric information on OF/BE-research. Neither the research sub-field as such, nor its structure or development, have been subject to systematic analysis before.

Therefore, in order to test the hypothesis and to explore the field, this article aims at providing a systematic insight into the structure and development of research at the intersection of OF and BE by identifying and analyzing the corpus of scientific literature in the field. The goal is to quantitatively define the status of research in the context of OF and BE and to reflect on past and future developments in the field.

## 2. Methodology

### 2.1. Literature search

Research papers referring to both organic agriculture (OF) and bioenergy (BE) were gathered from the “ISI—Web of Science” database (WoS). The literature search was conducted via topic search (TS) including articles' title, abstract, author, keywords, and KeyWords Plus. Thomson Reuters' KeyWords Plus are index terms created from significant, frequently occurring words in the titles of an article's cited references.

Boolean operators were used to combine search terms as follows:

(i) agriculture in general (AGR):
TS=(agriculture OR farm*),
(ii) organic farming (OF):
TS=(“organic agriculture” OR “organic farm*”), and
(iii) bioenergy (BE):
TS=(“bioenergy*” OR “biofuel*” OR “bioethanol*” OR “biodiesel*” OR “biogas*” OR “anaerobic digestion”).

By combining the three search sets the relevant articles in agricultural bioenergy research (AGR/BE) and organic agricultural bioenergy research (OF/BE) were filtered from the search results. Results were limited to articles in English language. The timespan included January 1980 until March 2012, thereby, taking into account that both bioenergy production and organic agriculture were hardly subject to scientific investigation before the 1980s. Also, preliminary searches of WoS showed that there has not been a continuous publication activity in OF or BE, respectively, until the mid-1980s.

### 2.2. Literature analysis

The unit of analysis is the individual paper. In order to describe the corpus of literature and to gather insights into the field of research, analysis focused on papers' year of publication, journal title, authors, authors' affiliation and country. Furthermore, journals were categorized according to their statement of aims and scope: (i) agriculture and agro-ecology, (ii) energy, biotechnology and engineering, (iii) socioeconomics, and (iv) environment and earth science.

In order to assess the importance of the field as such and as a sub-field of AGR/BE- and OF-research, respectively, the OF/BE-set was compared with the AGR/BE- and OF-sets as well as their relative shares in AGR-research. Comparisons were conducted between the sub-sets for the following variables: number of papers, journal category, author, and author's affiliation, as well as indicators for publication growth and development.

The development of the research fields was reviewed by the mean annual percentage rate of publication growth (MAPR; Eq. (1)), which frequently serves as a rough approximation to the growth of scientific knowledge [35]:

$$\mathrm{MAPR} = \frac{1}{t}\sum_{y=1}^{t} 100\,\frac{P_y - P_{y-1}}{P_{y-1}} \tag{1}$$

where $P_y$ is the number of papers in the $y$th year and $t$ is the analyzed time period in years.

Dynamics in the growth of the different fields of research were examined with the $2T$-equation (Eq. (2)) describing the doubling time of a corpus of literature in a certain time [36]:

$$2T = \frac{0.301(t-1)}{\log P_t - \log P_1} \tag{2}$$

where $P_1$ is the number of papers in the initial year and $P_t$ the cumulative number of articles in the $t$th year. Analysis of publication growth and sub-set comparisons were conducted for entire years only.

## 3. Results

The search identified 123,606 articles in the field of agriculture and farming in general (AGR) for the period of 1980 to March 2012. The basic set of BE-papers comprises of 22,124 articles. A sub-set of 1,266 AGR/BE-papers could be identified by combination of the two general sets of documents. The search resulted in another set of 2483 research articles with a focus on OF which completely represents a sub-set of AGR. The symbolic structure of the search sets is depicted in Fig. 1.

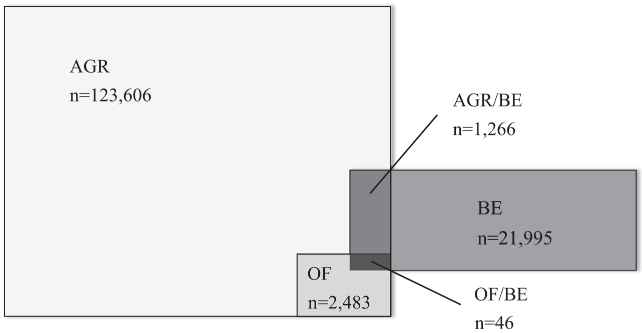



**Fig. 1.** Symbolic structure and sectional areas of the search sets (AGR=agriculture; BE=bioenergy; OF=organic agriculture; AGR/BE=agricultural bioenergy; OF/BE=organic agricultural bioenergy).

## 3.1. Development and dynamic of OF/BE-research

The search yielded 46 organic agricultural research papers with reference to the topic of bioenergy production or vice versa. A combination of the two topics does not appear regularly in the WoS database until the year 2004. Bioenergy research is not only a niche in organic agricultural science but also a rather new one. Before 2004 only 3 papers had been published: one each in 1992, '93 and '99 (Fig. 2). Since 2004 (1 OF/BE-paper) there is continuous publication activity with a recent peak of 11 research articles in 2011.

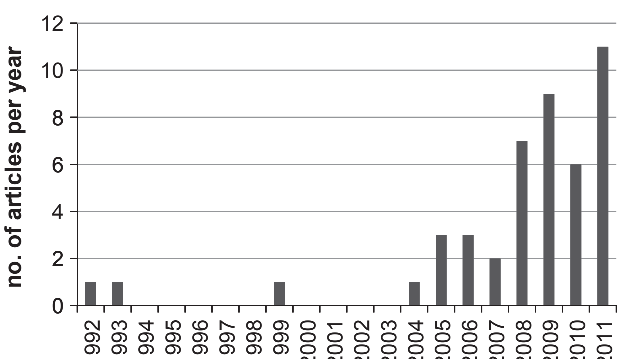



**Fig. 2.** Articles in the field of OF/BE in the years 1992–2011.

### 3.1.1. Publication growth

A strong publication growth can be observed in the field of OF/BE. For the years 2004 to 2011 the MAPR is averaging about 60%. This may partly be a sign of vivid scientific interest and increasing publication activity. However, to a large extent the high average growth rate is due to the small number of publications (Fig. 2). The initial phase of evolving research areas is characterized by low paper output and high variability in annual growth rates [35]. Standard deviation (SD) in the case of publication growth rates for OF/BE-articles during 2004 to 2011 is 101.

MAPR for the field of OF (13.5%; SD=8) has approximated that of AGR (10%; SD=5), whereas publication counts for AGR/BE have grown at an average rate of 40% (SD=25) in the years 2004 to 2011. Apparently, the agricultural bioenergy fields (AGR/BE and OF/BE) develop more dynamically than the agricultural sciences in general (AGR and OF). So while MAPR in OF/BE is very high, MAPRs in the established research fields with continuous publication activity since the 1980s (OF and AGR/BE) are lower, but in case of AGR/BE-papers not significantly lower than for the field of OF/BE. Nevertheless, the low absolute number of articles makes it difficult to compare publication development in newly evolving OF/BE and the agricultural sub-fields OF and AGR/BE via absolute numbers and MAPR.

Comparisons of the first 8 years of continuous publication activity in OF/BE (2004–2011) with the early phases of OF- or AGR/BE-research might show tendencies of how strong the particular topic developed when it was first subject to scientific interest. However, comparing the years 2004–2011 with an 8 year timespan in the late 1980s and early 1990s would not be valid, since the scientific publication behavior and its relevancy have undergone dramatic changes, as has the overall situation of research and science publishing [35].

### 3.1.2. Doubling time

In contrast to the MAPR the logarithmic $2T$ function for calculating the doubling time of research articles is not as biased by highly divergent publication counts when comparing fields of science [35]. In AGR the cumulative publications in the recent past (2004–2011) double every other year ($2T=1.93$ years) while OF publications double only slightly sooner ($2T=1.81$ years) (Table 1). Again, the different evolutionary stages of the research fields are only partly represented by their doubling time. Although the chronology of research on AGR/BE is similar to OF (beginning in the early 1980s), cumulative AGR/BE-publications show a considerably lower doubling time ($2T=1.27$ years) than OF. OF/BE-publication dynamic with a doubling time of 1.30 years is almost not differing from the developments in AGR/BE.

**Table 1**
Doubling time of scientific publications in agricultural science (AGR) and its sub-fields (AGR/BE; OF; OF/BE) in 2004–2011.

| Field of research | Doubling time (2004–2011) |
|---|---|
| AGR | 1.93 |
| AGR/BE | 1.27 |
| OF | 1.81 |
| OF/BE | 1.30 |

### 3.1.3. Status of the sub-fields

According to the search results 1% of all AGR-papers are related to bioenergy (AGR/BE). Almost twice as many (2%) are related OF. Despite the low absolute number of scientific articles in the field of OF/BE, the percentages show that BE is a topic in OF-papers almost twice as often as in AGR-publications in general (Table 2). In the field of OF 1.9% of all research papers are related to bioenergy whereas only 1% of all AGR-papers are related to bioenergy.

## 3.2. Distribution and structure of OF/BE-research

The distribution of scientific publishing generally reveals distinct patterns. According to Bradford's law of scattering, the distribution of authorship in scientific publishing resembles an exponential function [37]. In the present study, the majority of institutions that researchers are affiliated with were engaged in no more than 1 article while very few countries and institutions, respectively, produced the majority of research papers. Results show that despite the small number of articles on OF/BE Bradford's law on the distribution of scientific output applies in this sub-field as well.

### 3.2.1. Country and affiliation of authors

Research activity represented by the analyzed research articles is mainly concentrated in Europe (Table 3). The most important countries for researchers in the field of OF/BE are Sweden, Germany and Denmark. Researchers from these 3 countries

**Table 2**
Number of articles identified for the timespan 1980–March 2012 in the different fields of research and the relative share of their sub-sets (AGR/BE; OF; OF/BE).

| Field of research | Number of articles | Percentage of articles from the field of. | | |
|---|---|---|---|---|
| | | AGR/BE | OF | OF/BE |
| "agriculture" (AGR) | 123,606 | 1.0 | 2.0 | 0.04 |
| "agriculture" AND "bioenergy" (AGR/BE) | 1,266 | 100.0 | – | 3.6 |
| "organic agriculture" (OF) | 2,483 | – | 100.0 | 1.9 |

**Table 3**
Regional distribution of the authors contributing to 46 research papers from the field of OF/BE (regional/national sums may not equal $n=46$ due to international co-authorship).

| Region | Country | Number of articles ($n=46$) |
|---|---|---|
| Europe | | 36 |
| | Sweden | 11 |
| | Germany | 8 |
| | Denmark | 7 |
| | England; Slovenia; Spain | 2 each |
| | Austria; Finland; Greece; Netherlands; Romania; Scotland; Switzerland; Turkey | 1 each |
| America | | 5 |
| | United States | 2 |
| | Brazil; Canada; Chile | 1 each |
| Asia | | 5 |
| | PR China; Philippines | 2 each |
| | Pakistan | 1 |

**Table 4**
Affiliations of the authors contributing to 46 research papers from the field of OF/BE and the institutions' publication activity in the fields of OF and AGR/BE (limited to institutions with $>1$ OF/BE paper).

| Institutions | Number of articles (rank according to absolute number of articles published in the field); share of OF/BE articles | | |
|---|---|---|---|
| | OF/BE | OF | AGR/BE |
| Swedish Univ. of Agricultural Sciences, SE | 11 | 107 (3); 10.3% | 41 (2); 26.8% |
| Aarhus University, DK | 6 | 121 (2); 5.0% | 9 (21); 66.7% |
| University of Hohenheim, DE | 4 | 21 (19); 19.0% | 11 (18); 36.4% |
| Lund University, SE | 2 | 12 (44); 16.7% | 13 (13); 15.4% |
| Technical University of Denmark, DK | 2 | 8 (83); 25.0% | 11 (18); 18.2% |
| Justus Liebig University of Giessen, DE | 2 | 18 (26); 11.1% | 3 (−); 66.6% |
| Johann Heinrich von Thünen Institute, DE | 2 | 10 (61); 20.0% | 6 (40); 33.3% |
| University of Maribor, SLO | 2 | 13 (40); 15.4% | 2 (−);100.0% |
| German Biomass Research Centre, DE | 2 | 2 (−);100.0% | n.a. |

participated in the publication of 26 of the 46 articles. Authorship is not equally distributed among institutions but rather concentrated at a few institutions, mostly universities. Within the countries with above average publication frequency (Sweden, Germany, Denmark) the authors are mainly concentrated at one or two research institutions.

With their contribution to all 11 Swedish articles researchers at the Swedish University of Agricultural Sciences (SLU) and its associated research institutes are the most productive in the context of OF/BE (Table 4). In Germany, concentration does not seem as evident since authors and co-authors of a total of eight articles located here are affiliated with four different research institutions. However, the analysis of the funding institutions showed that six of the eight papers originated from a single research project at the Justus-von-Liebig-University of Giessen and that different author affiliations simply reflect the post-project employment of the researchers. Aarhus University and the Technical University of Denmark on the other hand represent two different focal institutions of Danish research in OF/BE. However, projects seem to be interrelated and cooperation in the publication of the 7 Danish articles suggests connections between the Danish institutions.

Considering the publication frequency of the research institutions in the different scientific sub-fields, the most prominent institutions in OF/BE-research are highly active in publishing in either one or even both of the OF- and AGR/BE-fields as well (Table 4). SLU ranks 3rd in WoS listed publications on OF and 2nd in AGR/BE-papers. The Aarhus University even takes rank 2 in WoS listed OF-papers. On the other hand Aarhus' paper output in the field of AGR/BE is only ranking 21st. Evidently, there is some research activity on AGR/BE in Aarhus that allows for a synthesis with the prominent OF topic. It is, however, secondary with a total of less than 10 research articles identified in this study. The world's leading institution in OF-publications according to WoS, Wageningen University and Research Centre in the Netherlands, is missing in the field of OF/BE-research. Hence, a high activity in organic agricultural science is not sufficient inducement for engaging in the combined research field. Not even when in addition there is a considerable engagement in AGR/BE-research as in Wageningen, which is ranking 7th in agricultural bioenergy papers in general.

#### *3.2.2. Authors*

A total of 102 authors contributed to OF/BE-papers, averaging 2.2 authors per article. Collaborative authorship is slightly more prevalent in OF (2.4 authors/article) and AGR/BE (2.6). The field of OF/BE represents a niche, a sub-sub-field of AGR- and BE-research, respectively. However, among the 18 authors with 6 or more published papers in the field of AGR/BE there are 9 who also participated in publications on OF/BE. All 6 authors with 6 or more research articles in the field of OF/BE are also among these top 18 contributors to AGR/BE-publications.

#### *3.2.3. Journal*

The 46 articles are scattered over 32 journals. Only 8 journals published more than one article. These 8 core journals account for 22 of the 46 papers in OF/BE. Several journals from different disciplines engaged in the publication of the articles. Apart from Biomass and Bioenergy which is the journal with the most published papers (5) and Bioprocess and Biosystems Engineering (2), the journals with 2 or more research papers represent a clear agricultural focus. In total, 15 of the 32 journals focus on agricultural or agro-ecosystem research and are responsible for 24 of the 46 papers. Another 13 papers have been published in one of the 8 Energy/Biotechnology journals. The remaining 9 articles were found in 9 different journals with their scope in various fields such as earth sciences, environmental engineering, politics or management.

## 4. Discussion

### *4.1. Status and development*

OF/BE is a rather new field. Research at the intersection of organic agriculture and bioenergy is a niche in agricultural as well as in bioenergy science. Although this is self-evident because the study narrowly defined the relevant corpus of literature as sub-sub-field of the two general research areas AGR and BE, it may be regarded as surprising—not only because of the urgency of the two topics in regard to current sustainability challenges described above, but for several other aspects:

1. Within their research agendas institutions and stakeholders of the organic food and farming sector have been stating bioenergy as a pressing future topic of organic agricultural sciences [38,39]. Thereby acknowledging the topic's importance and promoting initial research efforts in this direction.
2. There have also been calls for an ecological intensification of organic farming systems to further enhance productivity and energy efficiency [38,39]. This is no novelty: In traditional Chinese agriculture e.g. bioenergy production was an integral part of farming systems. Anaerobic digestion of excreta and biomass residues provided gaseous fuel and played a major role in nutrient dynamics and continuous soil fertility [4]. It is their closed cycles for which these traditional production systems can be compared to modern organic principles. In respect of ecological intensification a coherent perspective in research efforts on modern bioenergy systems such as biogas and organic farming systems would be perspicuous as well.
3. Also, bioenergy research is showing growing interest in sustainability indicators, regulations and biomass certification schemes, in order to reduce or obviate negative repercussions of modern biomass supply for bioenergy systems [40]. Organic certification schemes are increasingly harmonized globally and have proven efficient and functional since the 1980s and may also be applicable for biomass production in organic farming systems.

With these aspects in mind and considering that in recent years (2004–2012) according to WoS there have been 210 research articles in the field of agricultural bioenergy (AGR/BE) concerned with genetic engineering, 46 AGR/BE-papers relating to OF in that same period are a relatively small number.

A possible explanation for this underrepresentation of the OF-topic in scientific publications on renewable and sustainable bioenergy might be the focus of OF-research. Research on OF is largely oriented towards knowledge transfer to practitioners [41]. A common self-conception in organic agricultural science is to serve the organic sector by research on applied problems. In this context the publication of results in peer-reviewed journals is often not a priority. This may contribute to the relatively few results when searching for OF/BE via WoS. A consideration of “grey literature” might lead to a different evaluation.

The relatively low absolute number of OF/BE-papers is also a sign of the early stage of OF/BE-research. For a newly emerging sub-field in AGR/BE research, however, it does not develop very dynamically. As the results have shown relative publication growth as well as the doubling time in OF/BE closely resemble those in the well-established field of AGR/BE. Since the general dynamic in AGR/BE publication is not linear, this is strong evidence that OF/BE is a sub-field of AGR/BE without independent dynamic.

### *4.2. Structure and distribution*

The descriptive analysis of the bibliometric data yielded information on the structure and characteristics of the research field. According to the results on author's affiliation as well as the journals' aims and scope, the focus of OF/BE-research is clearly agricultural in the sense that predominantly agricultural scientists concerned with organic farming play a leading role in the connection with bioenergy research and publish their findings in mostly agricultural journals. So while the research perspective is agricultural and in many cases organic agricultural, the development is closely related to AGR/BE in general.

Journals, institutions and authors with a background in engineering and biotechnology are represented far less. This may be due to the constraints that small niches are facing in science funding and publishing. Technology development or research in a niche might not be as rewarding scientifically speaking and probably not as promising from a commercial viewpoint. Structural barriers to new topics or approaches in technoscientific sustainability research resulting from political fixes and scientific paradigms [42] may also be relevant for a rather slow integration of OF and BE.

In addition to the rather fragmented nature of biomass research in general [43], the OF/BE-subject is of interdisciplinary character. Organic farming for food by itself is a complex system and the investigation of OF-systems requires trans- or multidisciplinary perspectives [44,26]. A connection with bioenergy will broaden the scope of research and increase the complexity of the topic even further. This assumption is supported by the thematic diversity of the publishing journals found in the present study. Furthermore, this may lead to barriers for research institutions to engage in OF/BE when they are lacking expertise in one of the relevant areas. This is also reflected in the results when considering that the most active institutions in OF/BE-publications are also active in either OF or AGR/BE or both. However, expertise in both OF and AGR/BE does not automatically lead to combined research activity in OF/BE. The absence of the Wageningen University in the sample of analysis is evidence for that. Also, the United States as the most active country in biomass research [45] as well as OF- and AGR/BE-publications, is represented with only 2 OF/BE-articles. It may well be assumed, that it takes special interest of at

least one of the actors (politics, funding institutions, researchers) for scientists to engage in combined research efforts on OF and BE.

Furthermore, the authors' high publication activity in the general fields of OF and BE, respectively, indicate a strong personal expertise of researchers involved with OF/BE research. Thus, it may be assumed that apart from the institutions' focus the individual expertise and research interests of scientists are of great importance for a combination of the two fields.

### 4.3. Perspective and conception

The present study concentrated on the quantitative characteristics of the ISI Web of Science database information only and did not analyze papers' contents in detail. However, the integration of OF- and BE-research may be conceived from different perspectives: (i) OF integrating BE; (ii) BE utilizing resources from OF; (iii) interrelations and influences of OF and BE as unintegrated parallel pathways. All of which were identified in the analyzed corpus of literature and could be investigated further.

The research community's strong interest in questions of bioenergy [45] and agricultural sustainability is a sign for the topics' continuous relevance in regard to current global challenges in energy production and farming. Reflecting this relevancy, the so-called Knowledge-Based Bio-Economy (KBBE) has gained prominence as agricultural research and development agenda in the European Union (EU) [46]. In the context of the KBBE and the EU already being the center of OF/BE-research our results underline that a coherent view on OF/BE in the EU might be a rewarding field for future research.

## 5. Conclusions

The combination of organic farming and bioenergy research is not only representing a niche in agricultural as well as bioenergy science, but also a fairly new one that has largely been driven by few focal institutions in Europe. From the mostly agricultural backgrounds of the institutions as well as the journals involved in the publications, we conclude that research interest in OF/BE is focused on agricultural systems rather than bioenergy technology and engineering.

The study has shown that despite the small absolute publication counts in the case of OF/BE-research a comparative sub-field analysis in the fields of agricultural science and renewable energy is possible. A characterization of niche topics, such as OF/BE, with simple descriptive scientometric methods is feasible and may yield valid information for the various stakeholders concerned with science policy as well as the renewable and sustainable energy research community. Although we thoroughly investigated the structure of the research field as such, a comprehensive content analysis of research literature on OF/BE that could emphasize research contents and reveal research gaps is still missing.

## References

[1] Jessop B. Economic and ecological crises: green new deals and no-growth economies. Development 2012;55(1):17–24.
[2] van der Ploeg JD. The food crisis, industrialized farming and the imperial regime. Journal of Agrarian Change 2009;10(1):98–106.
[3] Leach G. Energy and food production. Food Policy 1975;1(1):62–73.
[4] Wen D, Tang Y, Zheng X, He Y. Sustainable and productive agricultural development in China. Agriculture, Ecosystems & Environment 1992;39(1–2):55–70.
[5] Cleveland CJ. The direct and indirect use of fossil fuels and electricity in USA agriculture, 1910–1990. Agriculture, Ecosystems & Environment 1995;55(2):111–21.
[6] Dimitri C, Effland A, Conklin N. The 20th century transformation of US agriculture and farm policy. Washington, DC: USDA-ERS; 2005.
[7] Lanyon LE. Does nitrogen cycle? Changes in the spatial dynamics of nitrogen with industrial nitrogen fixation Journal of Production Agriculture 1995;8(1):70–8.
[8] Steinhart JS, Steinhart CE. Energy use in the U.S. food system. Science 1974;184:307–16.
[9] Foley JA, Ramankutty N, Brauman KA, Cassidy ES, Gerber JS, Johnston M, et al. Solutions for a cultivated planet. Nature 2011;478:337–42.
[10] Godfray HCJ, Beddington JR, Crute IR, Haddad L, Lawrence D, Muir JF, et al. Food security: The challenge of feeding 9 billion people. Science 2010;327:812–8.
[11] Naylor R. Expanding the boundaries of agricultural development. Food Security 2011;3(2):233–51.
[12] EEA (European Energy Agency). How much bioenergy can Europe produce without harming the environment? EEA report no 7/2006. Copenhagen; 2006.
[13] WBGU. German Advisory Council on global change—future bioenergy and sustainable land use. London: Earthscan; 2010.
[14] Cornelissen S, Koper M, Deng YY. The role of bioenergy in a fully sustainable global energy system. Biomass and Bioenergy 2012;41:21–33.
[15] Altieri MA. The ecological impacts of large-scale agrofuel monoculture production systems in the Americas. Bulletin of Science, Technology & Society 2009;29(3):236–44.
[16] Searchinger T, Heimlich R, Houghton RA, Dong F, Elobeid A, Fabiosa J, et al. Use of U.S. croplands for biofuels increases greenhouse gases through emissions from land-use change. Science 2008;319:1238–40.
[17] Thrän D, Kaltschmitt M. Competition—supporting or preventing an increased use of bioenergy? Biotechnology Journal 2007;2(12):1514–24.
[18] Jordan N, Boody G, Broussard W, Glover JD, Keeney D, McCown BH, et al. Sustainable development of the agricultural bio-economy. Science 2007;316:1570–1.
[19] Horlings LG, Marsden TK. Towards the real green revolution? Exploring the conceptual dimensions of a new ecological modernisation of agriculture that could 'feed the world Global Environmental Change 2011;21(2):441–52.
[20] Hansen JW. Is agricultural sustainability a useful concept? Agricultural Systems 1996;50(2):117–43.
[21] Cooper JM, Butler G, Leifert C. Life cycle analysis of greenhouse gas emissions from organic and conventional food production systems with and without bio-energy options. NJAS Journal of Life Sciences 2011;58(3):185–92.
[22] Pacini C, Wossink A, Giesen G, Vazzana C, Huirne R. Evaluation of sustainability of organic, integrated and conventional farming systems: a farm and field-scale analysis. Agriculture, Ecosystems & Environment 2003;95(1):273–88.
[23] Pimentel D, Hepperly P, Hanson J, Douds D, Seidel R. Environmental, energetic, and economic comparisons of organic and conventional farming systems. BioScience 2005;55(7):573–82.
[24] Tilman D, Cassman KG, Matson PA, Naylor R, Polasky S. Agricultural sustainability and intensive production practices. Nature 2002;418:671–7.
[25] Luttikholt LWM. Principles of organic agriculture as formulated by the International Federation of Organic Agriculture Movements. NJAS Journal of Life Sciences 2007;54(4):347–60.
[26] Watson CA, Walker RL, Stockdale EA. Research in organic production systems? Past, present and future Journal of Agricultural Science 2008;146(1):1–19.
[27] Leifeld J, Fuhrer J. Organic farming and soil carbon sequestration: what do we really know about the benefits? AMBIO: A Journal of the Human Environment 2010;39(8):585–99.
[28] Bengtsson J, Ahnström J, Weibull A. The effects of organic agriculture on biodiversity and abundance: a meta-analysis. Journal of Applied Ecology 2005;42(2):261–9.
[29] Maeder P, Fliessbach A, Dubois D, Gunst L, Fried P, Niggli U. Soil fertility and biodiversity in organic farming. Science 2002;296:1694–7.
[30] Dalgaard T, Olesen JE, Petersen SO, Petersen BM, Jørgensen U, Kristensen T, et al. Developments in greenhouse gas emissions and net energy use in Danish agriculture—how to achieve substantial $CO_2$ reductions? Environmental Pollution 2011;159(11):3193–203.
[31] Rigby D, Cáceres D. Organic farming and the sustainability of agricultural systems. Agricultural Systems 2001;68(1):21–40.
[32] Dalgaard T, Halberg N, Porter JR. A model for fossil energy use in Danish agriculture used to compare organic and conventional farming. Agriculture, Ecosystems & Environment 2001;87(1):51–65.
[33] Durusoy I, Turker MF, Keleş S, Kaygusuz K. Sustainable agriculture and the production of biomass for energy use. Energy Sources, Part A: Recovery Utilization, and Environmental Effects 2011;33(10):938–47.
[34] Muller A. Sustainable agriculture and the production of biomass for energy use. Climatic Change 2009;94(3):319–31.
[35] Vinkler P. The evaluation of research by scientometric indicators. Oxford: Chandos Publishing; 2010.
[36] Burton RE, Kebler RW. The "half-life" of some scientific and technical literatures. American Documentation 1960;11(1):18–22.
[37] Vickery BC. Bradford's law of scattering. Journal of Documentation 1948;4(3):198–203.
[38] Niggli U, Slabe A, Schmid O, Halberg N, Schlüter M. Vision for an organic food and farming research agenda 2025. Organic knowledge for the future. Brussels and Bonn: TP Organics; 2008.
[39] Rahmann G, Oppermann R, Paulsen HM, Good Weißmann F. but not good enough? Research and development needs in organic farming Agriculture and Forestry Research 2009;59(1):29–40.

[40] Scarlat N, Dallemand JF. Recent developments of biofuels/bioenergy sustainability certification: a global overview. Energy Policy 2011;39(3):1630–46.
[41] Bull CT. Organic research at the USDA: agricultural research service is taking root. Journal of Vegetable Science 2007;12(4):5–17.
[42] Diedrich A, Upham P, Levidow L, van der Hove S. Framing environmental sustainability challenges for research and innovation in European policy agendas. Environmental Science and Policy 2011;11(8):935–9.
[43] Thomas SM. The evaluation of plant biomass research: a case study of the problems inherent in bibliometric indicators. Scientometrics 1992;23(1):149–67.
[44] Aeberhard A, Rist S. Transdisciplinary co-production of knowledge in the development of organic agriculture in Switzerland. Ecological Economics 2009;68(4):1171–81.
[45] Manzano-Agugliaro F, Alcayde A, Montoya FG, Zapata-Sierra A, Gil C. Scientific production of renewable energies worldwide: an overview. Renewable and Sustainable Energy Reviews 2013;18:134–43.
[46] Levidow L, Birch K, Papaioannou T. Divergent paradigms of European agro-food innovation: the knowledge-based bio-economy (KBBE) as an R&D agenda. Science, Technology, & Human Values 2013;38(1):94–125.